Analysis of ISAAC Dayglow and Nightglow Spectra: Implications for Nitric Oxide, Atomic Oxygen, and Excited States of O_2

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Award Number: N00014031073

LONG-TERM GOALS

The goals of this project are to advance our understanding of physical and chemical processes in the upper mesosphere and thermosphere involving nitric oxide, atomic oxygen and excited states of molecular oxygen. Improved knowledge of the upper atmosphere will be directly related to applications for diagnosing and forecasting space weather phenomena.

OBJECTIVES

The scientific objectives of this project are to analyze spectral radiances measured by the ISAAC (Ionospheric Spectroscopy and Atmospheric Chemistry) instrument to retrieve vertical profiles of nitric oxide (NO) from 80 to 200 km, atomic oxygen above 120 km, and excited states of molecular oxygen between 90 and 120 km. The ISAAC instrument was launched in February 1999 onboard ARGOS, the Air Force Advanced Research and Global Observing Satellite. This study is focused on data obtained within the first year during November and December 1999, and between 40N to 70S latitude. The analysis includes constraints on instrument sensitivity, and in flight assessments of stray light and solar scattered background contributions.

APPROACH

The ISAAC instrument is a moderate resolution, middle ultraviolet (MUV) limb imager designed to observe thermospheric N_2, O, O_2, and NO with applications to space weather, solar forcing, and anthropogenic effects contributing to global warming. It is based on a heritage of earlier designs from the NRL Space Sciences Division. The high spectral resolution and wide temporal and latitudinal coverage afforded by the ISAAC observation can be leveraged to provide more information than previously possible. There are some difficulties in interpreting the ISAAC data, however, which are related to the exact computation of pointing tangent altitude, instrument sensitivity, stray light, and wavelength calibration. Although the ISAAC instrument was carefully characterized during pre-flight sensitivity and wavelength calibrations, changes in these important parameters can be expected to occur during the course of observations from the space environment.

The approaches taken in this project will utilize methods to characterize the ISAAC spectrograph characteristics while in orbit. The absolute sensitivity will be constrained using the observed intensity

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Analysis of ISAAC Dayglow and Nightglow Spectra:Implications for Nitric Oxide, Atomic Oxygen,and Excited States of O2**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Physics,New Mexico Institute of Mining and Technology,,Socorro,,NM, 87801**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

of Rayleigh-scattered sunlight as a function of altitude between 80 and 100 km. Stray light will be quantified using the method of spectral contrast, through comparison of solar Fraunhofer features observed in the Rayleigh-scattered signal to precise, direct solar irradiance measurements from spectrometers on the Upper Atmosphere Research Satellite. Systematic uncertainties in tangent altitude due to ARGOS pointing errors will be reduced using nightside observations of UV radiation from the molecular oxygen Herzberg emission layer. We will use standard profile retrieval techniques to obtain vertical profiles of emitting and scattering gases, including NO, O^+, and O_2. Interpretation of these profiles will involve the use of models such as the MSIS (Mass Spectrometer Incoherent Scatter) empirical model, and the NOX1DIM photochemical model.

Principal collaborators in this project include Dr. Kenneth Dymond and Dr. David Siskind from the E. O. Hulburt Center for Space Research, Naval Research Laboratory. Dr. Dymond is the primary contact for obtaining and analyzing the raw ISAAC data. Dr. Siskind is collaborating on the use of atmospheric models of the upper atmosphere.

WORK COMPLETED

The issues of instrument calibration and pointing uncertainties have been resolved for ISAAC data in the 2200-2400 Angstrom wavelength range for the November-December 1999 time frame. An observed dayglow spectrum from November 29, taken at about 1:00 pm local time near 20N latitude, is shown as a function of altitude in Figure 1. Below 90 km altitude, the bright signal of atmospheric Rayleigh scattering is evident. Between 100 and 180 km, there are isolated “spikes” in intensity that arise through fluorescent scattering in the gamma bands of NO. An intense oxygen emission line at 2470 Angstroms is also clearly observed.

Reliable techniques have been developed for removing the bright Rayleigh scattered background for extracting the NO gamma band intensity between 80 to 100 km. In addition, a method was established for in-flight characterization of detector nonlinear response. As a result, NO concentration profiles were retrieved over a broad altitude spanning the upper mesosphere to the middle thermosphere. The ISAAC nitric oxide data have been compared to near-coincident measurements from two other satellite sensors: the Halogen Occulation Experiment (HALOE) and the Student Nitric Oxide Experiment (SNOE). Photochemical model calculations were also completed in order to interpret the ISAAC nitric oxide results.

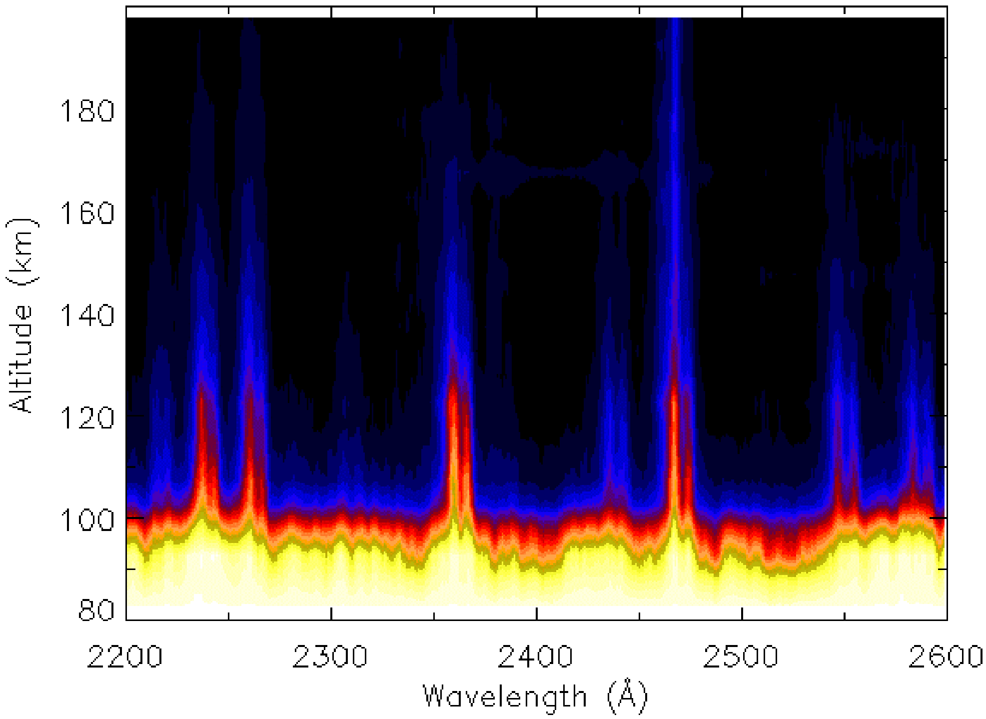

Figure 1. ISAAC ultraviolet radiation observed as a function of wavelength and altitude. The intensity scale increases from black (at high altitudes) to blue, red, green, and white (at the lowest altitudes).

RESULTS

We found that the flux of solar soft X-rays was important to the production of nitric oxide in the equatorial lower thermosphere. In this region, the ISAAC measured NO density shows a significant response to daily variations in the flux of solar soft X-rays observed by the SNOE instrument.

The ISAAC NO densities provide tight constraints on the profile of O_2 in the mid-to-upper thermosphere; our results favor the lower O_2 densities in the updated NRLMSISE-00 model as compared to MSIS90. The observed NO distribution also shows latitudinal gradients that reflect variations in thermospheric temperature and oxygen that are consistent with NRLMSISE-00.

IMPACT/APPLICATIONS

The above results are important for validating the improved predictions for thermospheric neutral densities in the NRLMSISE-00 model. In addition, the soft X-ray – nitric oxide correlation is evidence for solar-terrestrial coupling on daily timescales in the equatorial thermosphere. Both of these findings can ultimately lead to more accurate forecasts of space weather, with applications for predicting satellite drag and radio communication capabilities.

RELATED PROJECTS

None.

PUBLICATIONS

Minschwaner, K., J. Bishop, S. A. Budzien, K. F. Dymond, D. E. Siskind, M. H. Stevens, and R. P. McCoy, Middle and upper thermospheric odd nitrogen, 2: Measurements of nitric oxide from ISAAC observations of NO gamma band emission, *Journal of Geophysical Research*, [in press, refereed].